Renewable and Sustainable Energy Reviews 26 (2013) 685–693

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Overcoming barriers to low carbon technology transfer and deployment: An exploration of the impact of projects in developing and emerging economies

Matthew Kennedy [a,*], Biswajit Basu [b]

[a] Sustainable Energy Authority of Ireland, Wilton Park House, Dublin, Ireland
[b] Trinity College Dublin, Dublin, Ireland

A R T I C L E I N F O

Article history:
Received 6 March 2013
Received in revised form
21 May 2013
Accepted 26 May 2013
Available online 10 July 2013

Keywords:
Low carbon technology deployment
Barriers
Technology transfer
Impact assessment

A B S T R A C T

Through a case study investigation, this paper critically reviews and explores the impact of a number of projects within developing and emerging economies that are advancing low carbon technologies. It is in response to the challenge of better understanding the broad effect of imperfections and barriers that may alter the acceleration of such technologies. In analysing the impact of a number of projects, it highlights the challenges that projects are encountering and attempts to provide some valuable guidance for policy makers. The paper considers the realms of regulatory, institutional, financial and information frameworks that may prevent the accelerated development of markets for low carbon technologies. It concludes that such barriers have implications for energy policy and presents some lessons and potential actions that can aid policy makers, market actors and technology innovators in understanding the transfer and deployment of low carbon technologies.

Contents

* Corresponding author. Tel.: +353872650621; fax: +35318082002/+35318082070.
E-mail addresses: matthew.kennedy@seai.ie (M. Kennedy), basub@tcd.ie (B. Basu).

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.05.071

1. Introduction

Governments face global environmental and security challenges as they strive to reduce fossil dependence and achieve affordable energy to meet their economic aspirations. Global warming, carbon emission penalties and finite fossil fuel reserves have all contributed to a surge in low carbon technology deployment, pointing the way towards surmounting these challenges and achieving a more sustainable future. Moves toward climate stabilisation are enhanced through the deployment, diffusion and transfer of low carbon technologies aimed at reducing CO_2 emissions. Low carbon technologies, including both renewable energy and energy efficiency, could play a central role in meeting climate objectives by exploiting sources of energy and allowing cheaper, cleaner and more efficient methods of converting energy into desired end use services.

With the International Energy Agency (IEA) [1] and Organisation for Economic Co-operation and Development (OECD) [2] estimating that CO_2 emissions will double over the next four decades, a rise in average global temperatures of between 3 and 6 degrees, governments are being urgently asked to act to reverse these trends. The IEA's reference scenario [3,4] indicates that an 85% increase in global energy demand and 97% increase in energy related CO_2 emissions will come from developing countries by 2030. Developing countries and emerging economies are experiencing faster rates of growth in economic activity, industrial production, and urbanisation. Meeting their growth trajectory will require substantial technological investment that can enable a reorientation of the energy sector and a move towards low carbon technology deployment within the countries' energy mix.

Historically, the majority of technology transfer know-how and experience occurred between developed rather than to developing countries: between 1985 and 2004, 80% of the transfer of new mitigation technologies occurred between developed countries, while the remaining 20% was transferred between China, Korea and Taiwan [5]. In the past decade, low carbon technologies have attained significant patent investment in countries, especially within Europe, Japan and the United States (collectively holding 80% of patents, [6], and in emerging economies. Analysts [1,7–9] have called for a suite of low carbon technologies to be utilised, identifying the key technologies and their scale for deployment.

The transition to a clean energy economy requires a shift in the development trajectory of all countries. As the forecasted demand in developing countries is anticipated to increase, the smaller size and level of development of many of the energy systems and infrastructures may serve as an opportunity. As emerging economies become the significant energy user, focus could shift to the deployment of low carbon technologies and the transfer of advanced technologies that meet their longer term needs. Many countries, especially in Sub-Saharan Africa, are rich in energy resources but the deployment of new clean energy technologies have been eclipsed by emerging Asian economies of China, India and Indonesia (see Fig. 1). The increase in primary energy demand (Fig. 2) and associated emissions is projected to occur mostly in the developing world. As countries consider following a sustainable energy deployment pathway, they encounter barriers that may hinder the deployment of these technologies.

Through a case study analysis this paper explores the implementation challenges facing a number of low carbon technology projects. It identifies a number of lessons that could aid policy makers, project actors and innovators in overcoming or avoiding barriers that may hinder project implementation. Key findings across the suite of projects focus on the need to stimulate domestic environments through the development of enabling policies that enhance local actor capacity building, achieve institutional engagement and state support that bridge the financing gap. These lessons can influence successful low carbon technology project design, implementation and overall replication.

2. The role of barriers and imperfections

Low carbon technology transfer and deployment can flourish within a suitable enabling environment at a national level. Yet, there are a number of factors that influence the proliferation of low carbon technologies and prevent them from competing in the marketplace and achieving the necessary large scale deployment. Whether due to regulatory issues, financial capacities or lack of information, these barriers have the ability to significantly constrain their widespread deployment. They focus on high initial costs for technology deployment, transaction costs and the lack of an appropriate policy environment to enable such deployment [10]. The barriers that are encountered, and the tools to enable full

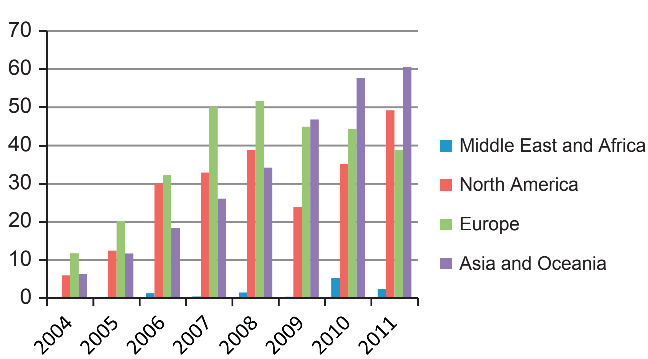

Fig. 1. Investment in New Renewable Energy by Region: 2004–2011 ($B) (after Bloomberg New Energy Finance [19]).

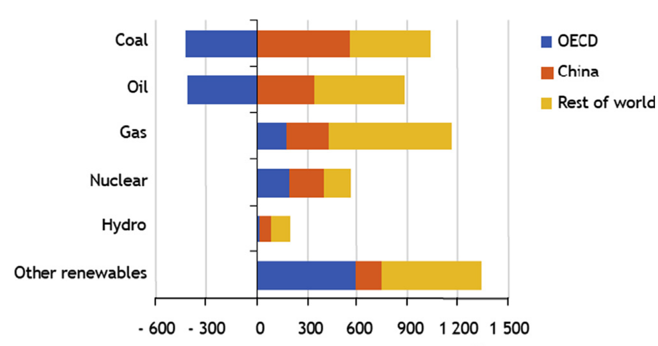

Fig. 2. Incremental Primary Energy Demand in new policies scenario 2008–2035 . (*Source* IEA, 2011)

technology transfer, differ significantly across countries and are often include regulatory barriers, a lack of information and policy uncertainty. Deficiencies remain in our understanding of economic and institutional frameworks, identifying and addressing barriers, and elaborating measures to overcome these barriers [11][1].

Governments must play a role in overcoming perceived barriers, often influencing and shaping the people, systems, techniques and knowledge and overall policy conditions. Such action could involve the provision of signals through stable energy investment policies, and the development of the national skills capacity by developing policy, legal frameworks and the institutional base for transfer. Creating an appropriate enabling environment to stimulate such energy projects involves a rethinking about how markets are created. In many developing countries such markets are heavily subsidized and regulated, with significant barriers or 'subtle imperfections' [12] that inhibit the efficient allocation and use of resources within that market.

As we move to understand the barriers that exist to the transfer and deployment of low carbon technologies, we explore the impact across a suite of five supported projects and draw lessons for policy makers in terms of actions to overcome technology transfer barriers. A number of examples of symptoms of 'imperfections' and barriers is presented in Appendix A. The next section categorises such barriers by three key groups: [Section 2.1] Policy, regulatory and institutional capacity; [Section 2.2] Investment and finance-related; and [Section 2.3] Information and technical barriers.

2.1. Policy, regulatory and institutional capacity barriers

Despite the existence of domestic and international financial incentives, regulatory and institutional barriers prevent the utilisation of low carbon technologies in both grid-connected and off-grid applications [13]. Interventions, such as international financial incentives, are only successful if they fit within national regulatory, legal and policy frameworks [13]. Undoubtedly, inconsistencies in the nature of low carbon technologies and uncertainties in technological performance remain key concerns as policy makers engage in technology push but fail to interact with stakeholders in formulating and adopting the use of these technologies.

In the realm of policy barriers, political barriers, in certain cases, can have a significant impact on the transfer of LCT to developing and emerging economies. Economic, social and political systems within individual countries, and outside them, negatively impact upon LCT deployment and transfer. Barriers to technology transfer tend to focus on patents, costs, and access to information rather than social or political factors. The Energy Group at the University of Sussex [16] investigated such barriers in technology transfer of low carbon energy technologies, acknowledging that relevant policy interventions vary according to the political and economic characteristics of both supplier and recipient technology. Furthermore, the development of nuclear energy has stalled across the EU, with government regulatory structures slowing construction time and added to expenses. Such regulatory hardships are alongside environmental controversies and waste management problems. Research by Suzuki [17], conducted across five case studies in India, describe how political instability may deter foreign investors, particularly where new commercial technologies are concerned. Furthermore, low levels of political commitment has led to a 'brain drain' across African countries as specialised researchers have moved to the US or Europe [18].

A renewed focus on supporting domestic policies to overcome domestic barriers is needed. Gboney [12] describes how, despite the Ghanaian Government's commitment to the deployment of renewable energy, the absence of a legal and regulatory framework was a major barrier to power producers wishing to invest in clean technologies. Haselip et al. [14], in analysing the pitfalls of policy implementation within the South African Feed-in-Tariff (REFIT), cited a lack of coordination and capacity at the policy making level, an unstable political environment and strong fossil fuel lobby groups as the main barriers to the implementation of the REFIT. This is further linked to technical barriers where a lack of appropriate skills in low carbon technology development was compensated for by impartial advice from energy expert in fossil fuel companies.

Within many developing countries, technical standards are limited, thereby negatively impacting on the deployment of low carbon technology into markets. Rao and Ravindranath [15] described how the Indian regulatory framework failed to enforce the use of renewable energy as a power option, thereby placing few incentives or obligations on utilities to deploy such clean technologies. Undoubtedly, the transfer of learning across jurisdictions can overcome regulatory barriers. From an EU perspective, the development of building codes and standards are one of the more successful policy tools that could be transferred and replicated. Such an approach, aimed at enhancing low energy building performance in China, is presented in Section 4.4.

2.2. Investment and finance-related barriers

A number of investment and finance-related barriers exist that could negatively affect the widespread deployment of low carbon technologies. Within developing country markets there is often limited knowledge and information concerning the benefits of investment and an overestimation of initial investment costs. This impacts upon judgement and provides reluctance for initialising project development. The risk-to-reward portfolio of technologies often results in domestic financial institutions' reluctance to invest. This is often based on a lack of understanding of risk assessment by local institutions. The development of innovative financing mechanisms and approaches in Mozambique and Uganda is presented in Section 4.3.

The impact of 'externalities', in the form of global fossil fuel subsidies, should be incorporated into detailed energy system models and considered by policy makers when shaping policy.[2] Recent estimates present fossil fuel consumption subsidies as amounted to $312 billion globally in 2009 [4] and show current fossil fuel subsidies as $409 billion compared to $66 billion for subsidies for renewable energy [19]. OECD analysis [2] showed fossil fuel support to the developed world amounted to $45–$75 billion in 2010, while clean energy subsidies amounted to $44 billion in 2010. Fig. 3 presents an economic value of renewable energy across two scenarios in the form of avoided cost that ranges from $2 trillion to $18 trillion. The economic value of fossil fuel consumption subsidies by country [2009] is presented in Fig. 4.[3]

2.3. Informational and technical barriers

Informational barriers exist that reduce the ability to optimise energy use. The domestic capacities of local actors, coupled with a

[1] Boldt et al. [11] identified 10 categories of barriers in their TNA Guidebook Series. These are extracted from Painuly's [33] categorisation of the generic barriers to the transfer and diffusion of climate technologies.

[2] Estimates show how the elimination of such externalities would result in a 6% reduction in global greenhouse gas emissions [6].

[3] Over 10 Sub-Saharan African countries are established oil producers with fossil fuel reserves and their major policy goal involves infrastructural development associated with supporting the oil and gas industry even though the majority of the population has off-grid access or no access to electricity [20]. From an Indian perspective, Rao and Ravindranath [15], in analyzing policies to overcome barriers in the bioenergy sector, described how, due to subsidies provided to the agricultural sector, the conventional costs of energy are maintained low so they neither reflect the true environmental costs nor even long-term life cycle costs.

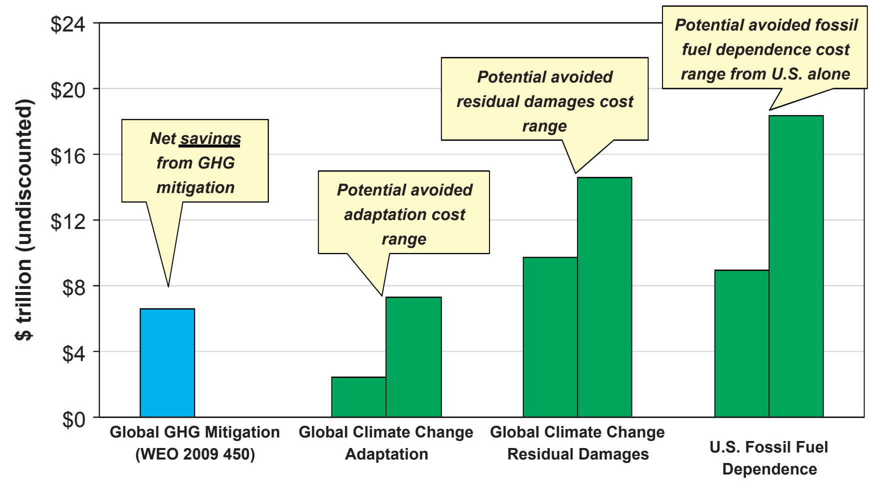

Fig. 3. Assessment of the Cost of Externalities [Scenario 6 RETD Project] Analysis carried out by the IEA RETD have classified these externalities by (a) adaptation costs, the costs of measures taken by humanity to adjust to climatic change [34], (b) damage costs, the costs of residual damage produced by climatic change that cannot be eliminated via adaptation, and fossil fuel dependence costs, the externality costs (excluding direct costs of supply) beyond climate change that are associated with maintaining the energy system's current dependence on fossil fuels.

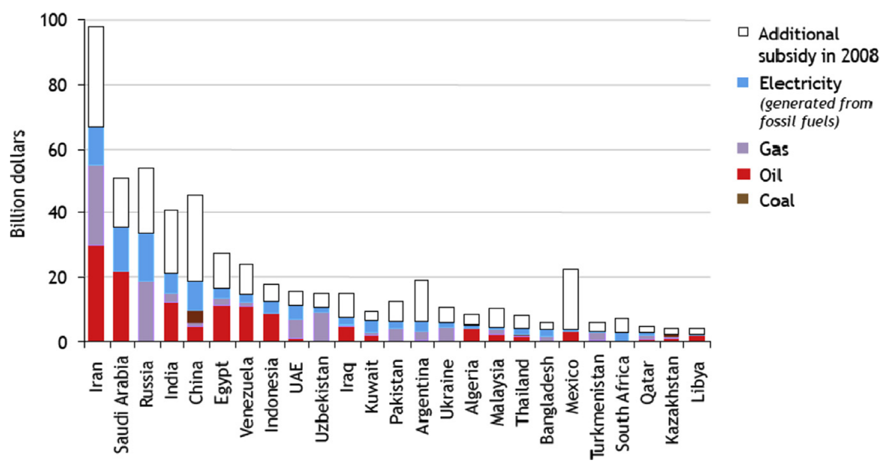

Fig. 4. Economic value of fossil fuel consumption subsidies by country, 2009 (IEA, 2011).

lack of information dissemination to enhance stakeholder awareness, often presents significant barriers to market uptake. In identifying barriers to the development of bioenergy in Thailand, Sajjakulnukit et al. [21] described a lack of awareness and confidence in available new energy technologies and applications, highlighting the requirement for extensive participation of stakeholders. The dearth of technical skills (for design, installation and operation, management and technology transfer) made many low carbon projects unsustainable in developing countries [12].

Energy policies become successful when interacted with other policy fields. Societal engagement through education and information campaigns should be 'adjusted to local conditions' [20], enabling the dissemination of information relating to cost, performance, and maintenance of technology systems. Indeed, Kaundinya [22], in describing a shift in bioenergy technology policy toward demand-pull, cited key weaknesses arising from the Indian Government's failure to consider the requirement to coordinate local, institutional and government support. Rao and Ravindranath [15], through their study of biomass system operation and maintenance in India, identified good practice actions, including policies to promote a participatory approach in planning and technology management, a periodic assessment of technologies and instruments to promote the demonstration of technologies.

3. Project selection

This section describes the process for selection of a suite of project interventions within developing and emerging economies that are advancing the transfer of low carbon technologies. It outlines an approach to assessing project impacts and highlights the local challenges that low carbon projects are experiencing.

3.1. Project selection methodology

A suite of developing and emerging economy projects are presented that have been individually evaluated and are supported by the Renewable Energy and Energy Efficiency Partnership (REEEP), an International UNFCCC Type II NGO. Each project was selected from a portfolio of projects that have been internationally evaluated by peer reviewers and funded by REEEP Government donors. These projects have not been previously highlighted, collectively grouped nor have their impact been assessed or cited internationally. Each project is confronts barriers and obstacles to the transfer and deployment of low carbon technologies. Additional selection criteria were applied to each project, namely the creation of an enabling framework for technology transfer and engagement in the process of developing Technology Action Plans as part of their needs assessment.

3.2. Project impact assessment approach

Technology impact assessment literature has identified various methods and tools to conducting thorough analysis and, over time, it has shifted in perspective, focus and approach. Significant debate [3,9,23] surrounds models, tools and scenario methods to measuring the impact of these technologies in countries that are currently dependent on hydro carbon systems.

More effective methods of assessment are required and current prevailing approaches do not feature in many government policies [24]. Across international institutions.[4] our exploration found that the impact associated with low carbon technology projects is predominantly assessed by a logical framework or outcome mapping approach. This captures such criteria as energy savings, clean energy generation, GHG mitigation, and developmental impacts, including employment creation and industrial development.

Our analysis found that policy makers often assess technology projects by means of cost–benefit and cost-effectiveness analysis, specifically in terms of employment creation, sustainability, environmental regeneration, trade and associated national development objectives. Accepting that technology assessment is an evolving area that continuously brings new challenges, it requires the invention of new methodologies and approaches to meet new demands [24]. While policy makers assess projects in terms of financial measures, including feed-in tariffs, related quantity based measures, subsidies, purchase agreements and publicly backed loan guarantees, the role of implementation actors that can transfer outputs into impacts and further adopt the use of these technologies is often diminished or not considered.

The variables analysed by the institutions within their impact assessment frameworks are often outside the sphere of control of the majority of international funding agencies. Often such agencies are reluctant to discuss the 'attribution gap' and often include elements that are contributed to by a number of different funding agencies. When analysing the impact assessment approaches applied by international institutions, this attribution gap often arises but is rarely considered.

Primarily, our assessment focuses on barriers to technology transfer as expressed in Sections 2.12.3. In analyzing the impact of such projects, we discount the logical framework and outcome mapping approaches in favour of a synthesis approach. This highlights non-technical aspects of projects, considers the role of implementation actors, and highlights locally appropriate indicators and local market systems to assess impacts. It is about determining the widest scope of impacts in society, or, put another way, "to better understand the consequences across society of the extension of the existing technology or the introduction of a new technology" [25]. Our synthesis approach places attention on the social and political context and participation and utilisation strategies [26]. It identifies local implementation actors that can transfer outputs into impacts and considers their interaction in formulating and adopting the use of these technologies. The projects selected highlight actor engagement, including a socio-economic impact of power systems on consumers, methodologies building capacity within developers' design decisions, and financing forums linking entrepreneurs with investors.

Lessons learned concerning potential project limited impact were cited where engagement at a provisional level would have heightened dissemination. Local implementation actors can transfer outputs into impacts, and potentially avoid donors' multiple counting and duplication through outcome mapping.[5] Strives are being made for a more integrated approach to project assessment with the objective of achieving more sustainable development goals. An assessment of resource utilisation and efficiency could place less stress on the environment. Authors often focus strongly on a systems dynamic modelling as a framework for technology sustainability assessment, while also calling for methods that account for the characteristics of sustainable development subsystems [28]. This could often involve the integration of social, economic and environment issues within overall assessment.

4. Exploring the barriers to technology transfer in developing and emerging economies

This section explores our understanding of barriers to low carbon technology transfer and deployment in the context of five individual projects selected. These case studies include a Village Power project to East Asia, a regulatory initiative for building energy efficiency in India, a finance advisory network in Africa, a low-energy building programme in China, and an informational initiative targeting the hospitality sector in Fiji.

4.1. Project 1: Dissemination of best practice of village power to East Asia

Village Electrification in Mongolia and China is high on their respective political agendas, implemented through the delivery of business models, such as Rural Energy Service Companies (RESCO). Indeed, the introduction of new technologies to rural areas remains a challenge as it generates changes in patterns of energy use that affect the demand of the system [29]. The World Bank "Renewable Energy Development Programme" commissioned a team of Chinese and international experts to elaborate a RESCO model in 2007/08 concerning the Chinese Township Electrification Programme, with a budget of €172,000. The Township Electrification Programme is the largest worldwide with regard to village power electrification by means of decentralized renewable energy systems. The principal purpose of this project is to transfer Chinese and international best practices of village power to East Asia countries via the establishment of a business model for PV village power in Mongolia.

In assessing the impact of the project, consideration was placed on its main activities and outputs included:

- Sharing of local experiences gained in the course of the electrification of rural villages by means of decentralized renewable energy technologies in China, Mongolia, North-Korea, and Japan.
- Summarising village power experiences in China and Mongolia focusing on financial models used.
- Development of a business model based on an installed village power system in Mongolia.
- Implementation of the business model produced; and
- Organisation of a regional workshop to disseminate lessons learning and study results.

[4] These institutions include the Global Environmental Facility, Clean Development Mechanism, United Nations Development Programme, the World Business Council on Sustainable Development and the Climate Investment Funds.

[5] For example, the United Nations Development Programme financed a socio-economic and environmental impact assessment to describe the impact of a bioenergy project in 'Henchengli Village' in the Jilin province of China. Good practice within this impact assessment, as described by Fischer et al. [27], included attempts to develop locally appropriate indicators to assess impacts, and the articulation of lessons learned to facilitate success in replicating projects in the future. In assessing the impact, root causes for project difficulties were blamed on 'inherent local deficiencies', including oversights in local capacity building, educational support, and failure to tap into local enthusiasm as local stakeholders were left without 'decision-making authority, corrective voice, administrative capacity, or technical capacity'.

4.1.1. Impact

Rural electrification by means of renewable energy has gained significant momentum in China and Mongolia, as verifiable by projects funded by World Bank, KfW Bank, and UN Development Programme. Village power as an approach to supply electricity to larger number of populations living in rural areas has become the favoured option under certain conditions. Village Electrification by means of renewable energy and the design of a sustainable business model, like RESCO, was a relatively new concept, since the recipient of such systems expected the government to take full responsibility for operation and maintenance. The main project challenges related to methods to ensure a sustainable operation, issues relating to transfer of ownership, the establishment of RESCOs, and analysis of the socio-economic impact on the rural population. As a result of this project, the Chinese Government is considering options to transfer the responsibility and ownership to state owned/private entities. This will enable state financed decentralized renewable energy systems to be commissioned, maintained and commercially operated in rural villages. Various recommendations and business models have been submitted to the National Energy Administration of China.

Assessing and measuring project implementation involved delivering a study focussed on the *Status of Utilization of RE in Rural Areas* in China and Mongolia. The village power questionnaires targeted the socio-economic impact of such village power systems on the consumers living and working conditions in these villages. In the past these ‘non-technical aspects’ were not considered when designing such projects. The bilateral exchange of information and experiences, training, elaboration of questionnaires has resulted in mutually increased user understanding of aspects related to village power electrification by means of low carbon technology. This is particularly the case in relation to operation and maintenance, socio-economic aspects, and service networks. Accumulated experience with renewable energy village power systems is a valuable reference used in the design of new projects planned by the government.

4.2. Project 2: Overcoming regulation and policy barriers in India

Studies carried out by the Energy and Resources Institute [30] show that more than 30% of Indian electricity can be saved in energy efficient buildings in comparison to conventional buildings. The City of Bangalore, India, is facing an enormous challenge to meet its ever growing demand of energy and water and to manage its ever increasing waste which is polluting the storm water drains and lakes in the city. There is a need to frame policies, regulations, guidelines, and develop financing instruments to achieve environmentally friendly, energy efficient buildings. The regulations need to be evolved to cover all aspects of sustainability and environment issues, including energy management, building materials and water/waste management. It is anticipated that the integration of compulsory regulations in the policy framework for buildings in Bangalore city will help conserve quantifiable tonnes of energy and abate CO_2 emissions.

In assessing the impact of the energy management policies to date, consideration was placed on the project's activities and outputs including:

– A framing of policies and regulations dedicated to energy management within Bangalore[6]; and
– The provision of a complete framework for municipal corporations, developers, builders, architects, technology providers, financial institutions aimed at promoting, developing and evaluating urban house performance to meet sustainability goals.

4.2.1. Impact

This project resulted in (a) the growth in the market for products to achieve energy efficiency and integrate renewable energy in buildings; (b) a reduction of CO_2 emissions from the building sector and (c) the prediction of energy saving and CO_2 emissions, arising after the policies and regulations framed through this project are legalised. It is expected that the building bye laws for the city of Bangalore will comprise of regulations and policies to integrate energy efficiency and renewable energy for both new and old existing buildings, thereby improving market demand for low carbon products. It is further anticipated that the policies and regulations developed to achieve energy efficiency and promote renewable energy in both new and existing buildings may be replicated by municipalities of other cities in India.

This project resulted in enhanced capacities of policy makers and practitioners. The developers are currently developing economic appraisal methodologies and life cycle saving analysis and will document findings to help building professionals to make design decisions with regards to introducing energy efficiency measures. A few simple calculation and assessment methods are being developed and provided as part of the web based tool. This will help building professionals make informed decisions to integrate energy efficiency for new and existing buildings. Post project actions included a government mandate on energy efficiency in all public buildings in the state, and a mandate on the use of solar water heating.

Pune, India, is a fast growing urban centre with increasing pressure on its resources. As a direct result of this project, policy recommendations were made to enable the government to implement the principles through regulations and byelaws. In order to incentivise eco housing in Pune, a set of technical criteria, with weighted point system, were established where TERI evolved the technical criteria for sustainable site planning and infrastructure planning, environmental architecture, energy efficient lighting, and renewable energy integration. The technical criteria and the weighting system have been developed through stakeholder consultation and impact assessment was made at household, local, and global level of the adoptable measures.

4.3. Project 3: Overcoming financial barriers in Mozambique and Uganda

While investments in low carbon projects have increased to a level of $1 billion annually in Africa in recent years, it is surprising that this accounts for only 1% of global total investment [20]. Policies and programmes aimed at rural electrification (Uganda) and efficient lighting (Ghana) have been successful, yet financing has been a major bottleneck. In 2010, a Private Financing Advisory Network (PFAN) was established in Mozambique & Uganda, replicating an existing initiative in East Asia, aimed at ‘bridging the gap’ between low carbon project developers and investors. The main activities, utilising a budget of $115,000, involved the screening of low energy business plans, selection of the most economically viable and environmentally beneficial projects, and provision of multiple rounds of coaching and guidance before projects are presented to investors. This involved development of a financing

[6] These policies and regulations include the following: energy demand reduction through appropriate architectural design features, energy efficiency in the cooling, heating systems and lighting, and appliances used in the building, integration of renewable energy to meet electricity demand in buildings, and energy demand reduction by meeting hot water demand in buildings through solar energy.

coaching and investor matchmaking service to guide low carbon projects to a bankable financial close.

In assessing the impact of PFAN to date, consideration was placed on its main activities and outputs including:

– Identification of projects for inclusion in PFAN's development pipeline for receipt of guidance on project development and financing;
– Transfer of a scalable Brazilian model to Mozambique as a pilot project for the cultivation of high value-added crops at the family farm level;
– Provision of technical assistance and training to raise the ability of local market players to develop new projects;
– Achievement of financial closure on 4–8 medium scale low carbon projects (biomass-to-energy, solar, small-hydro, biofuels etc), raising a total of USD $10–60 million; and
– Engagement on more than 30 projects across Africa.

4.3.1. Impact

An impact assessment of activities resulted in a significant reduction of the perceived obstacles to the mainstreaming of financing for clean energy projects in Mozambique & Uganda. This was due to the provision of increased access to financing networks and investment for local project developers and entrepreneurs, enabling a scale up of investment in projects. Consideration was also made of the project impact in contributing to the delivery of Millennium Development Goals (MDG) and removal of barriers. The PFAN projects enabled the development of capability in local institutions and created sustainable agricultural micro-enterprises utilising clean energy technology.

PFAN resulted in the development of an Africa Regional Network with dedicated Country Networks in Mozambique, Uganda and South Africa, enabling the transfer of a solar hydroponic project from Brazil to Mozambique. To January 2012, 21 Projects were 'closed' that account for USD$232 million of investment. Over 240 MW of clean capacity was installed, resulting in 1.26 million tCO_2 reduction per annum. Seven projects are currently in investor negotiations and an Africa Regional Clean Energy Financing Forum (AFRICEF) was delivered in 2010 and 2012, bringing together leading clean energy entrepreneurs in Africa with investors, fund managers and financiers that specialize in Africa's clean energy sector.[7]

4.4. Project 4: Promoting a low energy building programme in China

In China there was a significant lack of data concerning building energy performance throughout the 1980s and throughout the past decade energy consumption was growing at a much higher rate in the public sector than the residential sector. This led to questions about the existing buildings' compliance to current standards and the role of building controls and codes. Furthermore, questions were being raised about whether standards are appropriate and what "improvements could be made for enhancing the existing standards' availability and operability" [31, p446]. Focus was also placed on the lack of skills in the sector and requirements for improvement energy management standards through an effective enhancement of current policies and regulation. China's 12th Five Year Plan, [32] aims to reduce its energy intensity by 16% through projects including energy renovation and retrofitting, efficient product deployment and the use of performance contracting. The energy consumption in the building sector in China is 25% (around 4.5 billion CO_2e in 2007) of the nation's total energy consumption [31]. The official promotion of low energy buildings contributes to an overall reduction of energy consumption and the protection of the local and global environment in terms of reduced CO_2 emissions. From a governmental perspective, promoting a low carbon building programme could provide a number of social, health and employment impacts. However, the current prevailing price regime for electricity does not give sufficient financial incentives to developers due to the pay-back time for the additional investment required for such buildings is simply too long.

This project was developed to assist the continued concerted Government efforts designed to promote the construction of low energy buildings in China with the aim of contributing to a reduction of the overall energy consumption. Its purpose (utilising a budget of €120,000) was to reduce the energy consumption in buildings through the adoption of new standards based on international best practices of energy efficiency technologies and renewable energy use by the Chinese government.

In assessing the impact of the low energy building programme to date, consideration was placed on its main activities and outputs included:

– A review of the major experience of energy use in Europe and estimate of the energy savings achievable in China's building sector, with the assistance of European experts from the Netherlands, Germany and Austria;
– A review of best practices of sustainable building programmes in European countries, and introduction of European standards to China;
– An increased awareness of concepts for sustainable building development for several key stakeholder groups; and
– The development of policy recommendations for a sustainable building programme in China to promote the incorporation of energy efficiency and renewable energy technologies into the building sector.

4.4.1. Impact

The construction of low energy buildings has gained significant momentum in China, possibly triggered to some extend by the Olympic Games and the World Expo in Shanghai in 2010. This has led to an increased awareness among relevant stakeholders representing the Government, industry and public sector. The project enabled market development due to an intensified encouragement of the Government via the enactment of stricter building codes and regulations combined with financial incentives. In addition, the awareness was enhanced with regard to EU building standards among stakeholders representing the science, research, building sector industry field and the Ministries of Construction and Science and Technology.

The communication of this project was limited to the national level and involved experts only. It unfortunately avoided local authority engagement, achieved little involvement of stakeholders, and, therefore, affected the overall impact that limited the scope and framework in which the results have been disseminated. An engagement of stakeholders on the provincial level would have facilitated an analysis of EU buildings standards and its relevance and applicable aspects to China would have been disseminated to concerned stakeholders. Provinces are authorised to endorse their own building codes as long as they do not contradict national regulations.

[7] Ten projects were selected for their commercial viability and environmental benefits from over 65 project proposals and have all received intensive coaching on the preparation of their business plans from CTI PFAN professional advisors. Further project replication is anticipated in 2013 with the establishment of Sub-regional Networks in Africa. This includes (1) Southern Africa/ SADC (RSA, Mozambique, Tanzania, Botswana) (2) EAC: Uganda, Kenya, Rwanda and (3) West Africa: (Ghana, Togo, Cameroon).

Consequently, the potential to introduce new or amended building codes for low energy houses on the provincial levels was not addressed.

4.5. Project 5: Overcoming market information barriers in Fiji

This initiative focuses on the market development requirements that will enable and assist Fijian hotels and resorts in meeting the United Nation's World Tourism Organisation target of 20% energy saving and a 10% increase in the use of renewable energy technologies. A number of significant barriers have been identified within Fiji concerning the deployment of energy conservation measures and efficiency technologies. Consumers, communities, entrepreneurs and NGOs require information to enable them to undertake analysis of available technological alternatives before making an uptake or investment decision. This project was established by Greenlight Technology as an attempt to reduce the informational barriers to energy efficiency and renewable energy technologies confronting Fiji's hotel & resort sector.

In assessing the impact of the promotion programme to date, considertion was placed on its main activities and outputs including:

– The development of a structured market place for low carbon technology services and solutions tailored to Fiji's hotel and resort sector;
– A raising of awareness and creation of market demand for a range of small-scale low carbon energy technologies and services available to the hotel & resort sector;
– The development of a strategic plan for implementing a range of low carbon energy solutions in the Fijian hotel & resort sector; and
– The coordination of a collective reduction in electricity usage and CO_2 emissions, and offering the hotel sector vital cost relief in the face of a global economic downturn.

4.5.1. Impact

The project has developed an energy efficiency and renewable energy programme for the Fijian Hotel sector. This includes a hotel efficiency and renewable energy on-line 'market-place' bringing together technology and service firms and hotel owners and operators. Informational publications were provided to Fijian Hotel and Resort industry. Greenlight Technology established a local partnership in Fiji to facilitate the project and provide long-term benefits to the community that resulted in a reduction of the informational barriers to energy efficiency and renewable energy technologies confronting Fiji's hotel & resort sector. Importantly, from an industrial voluntary agreement perspective, the project formed a strategic alliance of key stakeholder in the Fijian hotel and resort sector focused on energy efficiency and renewable energy improvement investment.

5. Findings and lessons learned

This paper highlights a number of examples where low carbon technologies are being deployed and transferred within developing and emerging economies. In considering the regulatory, institutional, financial and informational barriers that that hinder and constrain the low carbon technology deployment in developing and emerging economies, this paper draws a number of lessons. It's main purpose is to identify the lessons for Government, market actors and technology innovators actors that can help erode and overcome such barriers to the transfer and deployment of low carbon technologies.

In our analysis of barriers across the suite of five projects analysed we present a number of findings and lessons including how:

– Domestic policies can facilitate the overcoming of domestic barriers and transfer learning across institutions and erode regulatory barriers.
– Local institutional and governmental support is crucial for technology demonstration and adoption and such institutions should improve their understanding of project risk assessment mechanisms.
– A lack of awareness and confidence in new technologies can be overcome through stakeholder engagement and enhanced participation. Local stakeholder engagement is critical for project success and can be stimulated through targeted information, training and experience exchange.
– Local engagement with policy makers, developers and practitioners can aid project implementation and project design decisions and, through local alliances, can erode informational barriers. Bilateral information exchange, dissemination and sharing of experience can help project design and replication and should be adjusted to local conditions.

Table 1
Potential actions that can aid the deployment of low carbon technologies.

Stakeholder/actor	Policy, regulatory & institutional	Investment and finance	Information and technical
Government	Technical plan analysis, including understanding of the technical potential, leading to the development of support schemes and regulation	Development of incentive schemes and support structures to assist with the roll-out of low carbon projects and distributed energy schemes	Education of consumers to raise awareness of long term vision for energy and CO_2 reduction for low carbon deployment
	Replication/consideration of EU best practice policies and regulations for energy use and low carbon deployment	Continued development, monitoring and analysis of support schemes and adjustment to support maximum potential uptake of measures	Monitoring of progress in reducing energy and CO_2 emissions against targets
	Establish new regulations to support small scale electricity generation		Continuation of education to support behavioural change
Markets & supply chains	Development of technology performance standards to provide consumers with guarantees of minimum levels of performance	Development of new business models to support uptake of low carbon technology measures/ installations	Training and education of designers and installers of energy measures
Technology & innovation actors	Development of low carbon products, technologies, standards and materials for increased efficiency from building regulations	Promotion of new business opportunities	Continued RD&D of market specific low carbon technologies
	Continued integration of low carbon generation with the electricity grid		

– Financial barriers can be overcome by strengthening local capability, making financing schemes available, and utilising economic appraisal methodologies and analysis to enhanced capacities of policy makers and practitioners.
– Initiatives that bridge the gap between investors and projects developers can include entrepreneurship and investor brokerage, enabling access to finance networks, and investor matchmaking. Such initiatives can overcome mainstream financing obstacles, scale up investment and build local institutional capacity.

Table 1 presents a number of potential actions that can aid policy makers, market actors and technology innovators in their understanding of the transfer and deployment of low carbon technologies.

Appendix A

Symptoms of typical barriers and 'imperfections' encountered in deploying low carbon technologies:

- Policy, regulatory and institutional capacity: Symptoms include political instability; bureaucracy; insufficient legal framework; poor market infrastructure; market control by incumbents; unsupportive external environment (such as high cost of regulatory compliance); low R&D investment.
- Investment and finance-related: Symptoms include a lack of access to finance; high upfront capital costs; inappropriate tariff incentives; subsidised electricity rates below cost recovery levels.
- Information and technical: Symptoms include a lack of consumer awareness; inadequate information and feedback loops; dearth of professional institutions; limited institutional capacity; lack of quality control, standards and codes; lack of skills and appropriate training; immature market development.

References

[1] International Energy Agency. World Energy Outlook; 2011.
[2] OECD, OECD Environmental Outlook to 2050; 2012.
[3] International Energy Agency. World Energy Outlook; 2008,.
[4] International Energy Agency. World energy outlook; 2012, International Energy Agency.
[5] Hascic, I Johnstone, N. (2009). The Kyoto Protocol and International Technology Transfer: An Empirical Analysis Using Patent Data; March 2009.
[6] OECD. Economic aspects of adaptation to climate change: costs, benefits, and policy instruments. In: Agrawala S, Fankhauser S, editors. Organisation for Economic Co-operation and Development; 2008.
[7] Stern, N., Stern Review, Report on the economics of climate change; 2006.
[8] IPCC, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change; 2007.
[9] Vattenfall, McKinsey. Global mapping of GHG abatement to 2030. Sweden: Vattenfall AB; 2007.
[10] Junfeng L, Li Z, Runqing H, Zhengmin Z, Jingli S, Yangin S. Policy analysis of the barriers to the renewable energy development in the People's Republic of China. Energy for Sustainable Development 2002;VI(3).
[11] Boldt J, Nygaard I, Hansen UE, Traerup S. Overcoming barriers to the transfer and diffusion of climate technologies, TNA guidebook series. UNEP RISO Centre; 2012.
[12] Lovins AB, Lovins LH. Climate: making sense and making money. Rocky Mountain Institute; 1997.
[13] Deutsche Bank, GET FiT Plus, Derisking clean energy business models in a developing country context. ⟨http://www.dbcca.com/dbcca/EN/_media/GET_FiT_Plus.pdf⟩ 2011.
[14] Haselip J, Nygaard I, Hansen U, Ackom E. Diffusion of renewable energy technologies: case studies of enabling frameworks in developing countries. UNEP RISO; 2011.
[15] Rao KU, Ravindranath NH. Policies to overcome barriers to the spread of bioenergy technologies in India. Energy for Sustainable Development 2002;VI (3) September 2002.
[16] Ockwell D, Watson J, MacKerron G, Pal P, Yamin F, Vasudevan N, et al. UK–India collaboration to identify the barriers to the transfer of low carbon energy technology. The Sussex Group; 2007.
[17] Suzuki, M., Finding the social, economic and technological barriers and opportunities in the developing countries for designing the technology transfer and innovation regime in climate change. ⟨http://edocs.fu-berlin.de⟩. 2010.
[18] Center for American Progress and Global Climate Network. Breaking through on technology overcoming the barriers to the development and wide deployment of low-carbon technology .2009.
[19] Bloomberg New Energy Finance. Michael Liebriech Lecture. Dublin.Institute for International and European Affairs; 2012.
[20] Koskimaki PL. Africa could take a leap to energy efficiency: what lessons could Sub-Saharan countries learn from European energy efficiency policy implementation. Energy for Sustainable Development 2005;16(2):189–96.
[21] Sajjakulnukit B, Maneekhao V, Pongnarintasut V. Policy analysis to identify the barriers to the development of bioenergy in Thailand. Energy for Sustainable Development 2002;VI(3).
[22] Kaundinya DP, Balachandra P, Ravindranath NH. Grid-connected versus stand alone energy systems for decentralized power: a review of literature. Renewable and Sustainable Energy Reviews 2009;13(8).
[23] Pacala S, Socolow R. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. Science 2004;305(5686):968–72.
[24] Tram TA, Daim T. A taxonomic review of methods and tools applied in technology assessment. Technological Forecasting & Social Change 2008;75:1396–405.
[25] Coates JF. A 21st century agenda for technology assessment. Technological Forecasting and Social Change 2001;67:303–8.
[26] Ballard SC, Hall TA. Theory and Practice of integrated impact assessment: the case of the western energy study. Technological Forecasting and Social Change 1984;25:37–48.
[27] Fischer SL, Koshland CP, Young JA. Social, economic, and environmental impacts assessment of a village-scale modern biomass energy project in Jilin province, China: local outcomes and lessons learned. Energy for Sustainable Development 2005;IX(4).
[28] Musango JK, Brent AC. A conceptual framework for energy technology sustainability assessment. Energy for Sustainable Development 2011;15:84–91.
[29] Alvial-Palavicino C, Garrido-Echeverria N, Jimenez-Estevez G, Reyes L, Palma-Behnke R. A methodology for community engagement in the introduction of renewable based smart microgrid. Energy for Sustainable Development 2011;15:314–23.
[30] The Energy Resources Institute, Annual report 2008/2009. 2010.
[31] Jiang P. Analysis of national and local energy-efficiency design standards in the public building sector in China. Energy for Sustainable Development 2011;15:443–50.
[32] China 5 Year Plan, 2011–2015. 2011. ⟨http://cbi.typepad.com/china_direct/2011/05/chinas-twelfth-five-new-plan-the-full-english-version.html⟩.
[33] Painuly JP. Barriers to renewable energy penetration: a framework for analysis. Renewable Energy 2001;24:73–89.
[34] Agrawala S, et al. Plan or React? Analysis of adaptation costs and benefits using integrated assessments models. OECD Environment working papers, No. 23. OECD; 2010.